Coral reef resilience to climate change in CNMI; field-based assessments and implications for vulnerability and future management

Final Report to the USGS-PICSC

1. ADMINISTRATIVE

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2. PUBLIC SUMMARY

Reducing coral reef vulnerability to climate change requires that managers understand and support the natural resilience of coral reefs. We define coral reef resilience as: the capacity of a reef to resist and/or recover from disturbance given its probable exposure regime, and maintain provision of ecosystem goods and services. Spatial variation in exposure to disturbance and the resilience of reefs in the face of those disturbances will determine the fate of coral reefs within management jurisdictions. This project sought to: 1) undertake ecological resilience assessments in the Commonwealth of the Northern Marianas Islands (CNMI), which is in the west Pacific near Guam, and 2) collaboratively develop a decision-support framework with local manager partners for resilience-based management. Between 2012 and 2014, our team surveyed 78 sites along the 30-foot contour of the fringing reefs surrounding the most populated islands in CNMI: Saipan, Tinian/Aguijan, and Rota. These surveys, and complementary analyses using data from environmental monitoring satellites and computer models, included measurements and assessments of variables that are 'indicators' of the processes that underlie reef resilience (e.g., recruitment of new corals and the control of macroalgae on reefs by herbivory). The final results are scores for relative resilience potential that resulted in our ranking the survey sites within and among the islands from high to low resilience. We also assessed two proxies of anthropogenic stress: land-based sources of pollution (e.g., nutrients and sediments) and wave exposure and accessibility (e.g., fishing access). We found resilience potential to vary greatly within and among islands and set 7 custom criteria within a decision-support framework that identifies sites that warrant management attention. This project represents globally relevant progress in the novel approach of using resilience assessments to inform management decision-making. Uniquely, the project was undertaken highly collaboratively with local managers in CNMI that are using the results to inform resilience-based management and management planning.

3. TECHNICAL SUMMARY

The overarching project objective was to generate information on resilience and vulnerability to climate change that can contribute to, and even drive, coastal management decision-making in the Commonwealth of the Northern Marianas Islands (CNMI). The specific objectives of this project were to:

1. Assess the relative resilience potential of fringing reef sites around the islands of Saipan, Tinian/Aguijan and Rota in CNMI.
2. Prepare reports, maps, tables and graphics to aid in communicating our results to manager partners and present and discuss our results in meetings with managers.
3. Communicate advances in methods as well as our results and process to practitioners in the broader Pacific and Caribbean.

The objectives were expanded to include development of a decision-support framework that uses the resilience assessment and field survey results to identify sites that warrant management attention. All of the set project objectives were met.

[Obj. 1] Resilience indicator variables were measured or assessed at 50 fringing reef sites near the islands of Tinian/Aguijan and Rota to add to the 29 sites surveyed near Saipan in 2012. Field methods included a mix of point-intercept transects, quadrats, stationary point counts, survey swims and coral health assessments and data compiled from environmental monitoring satellites. Two proxies for anthropogenic stress, land-based sources of pollution (e.g., nutrients and sediments) and wave exposure and accessibility (e.g., fishing access) were assessed using geographical information systems data layers of wave height and land topography and use. Composite scores were produced of relative resilience potential and sites were ranked within and among islands.

[Obj. 2] All results were compiled into tables as well as ~25 custom map graphics. The resilience assessments and anthropogenic stressor mapping results were queried with 7 custom criteria we developed that identify sites that warrant management attention. Managers are now using the range of results produced in planning exercises and for education and outreach programs.

[Obj. 3] Currently, our team is in the final stages of preparing a manuscript for submission to a leading global change/environmental management journal. Our methods and results have been shared at two workshops and many meetings of local management agencies in CNMI and federal agencies in Hawaii. The project results will also be shared via a recorded webinar in April of 2015 as well as at conferences in 2015 and 2016. Further, our team has developed entirely new resilience assessment descriptions and guidance for managers for The Nature Conservancy's Reef Resilience Toolkit (www.reefresilience.org). This guidance will ensure others can replicate and adapt our process. This project was undertaken highly collaboratively with local managers in CNMI who claim that the results will inform resilience-based management and planning for the coming years.

4. PURPOSE AND OBJECTIVES

The overarching project objective was to generate information on resilience and vulnerability to climate change that can contribute to, and drive, coastal management decision-making in the CNMI. Understanding and assessing differences in resilience potential is critical to ensuring that: a) supporting and maintaining resilience is a management priority, and b) discussions about resilience result in tractable management action and strategy. Our broader project started in 2012 when the CNMI Coral Reef Initiative (CRI) provided money to the local Bureau of Environmental and Coastal Quality (now BECQ) to perform a reef resiliency study for the reefs around Saipan (CNMI DEQ 2013). A review of resilience assessment methodologies co-led by our co-lead PI also became available in 2012 (McClanahan et al. 2012). This paper recommended a site selection framework using 11 variables (see methods section below). These variables are perceived to have high importance to resilience in the scientific community with strong empirical evidence as contributing to either resistance potential or recovery capacity. The first field-based implementation of this methodology took place in Saipan in March 2012 and included 29 sites. Resultant outputs included the first spatial interpolation of a reef resilience assessment and a map of 'relative resilience potential' (low, medium or high) for all of the reef areas surrounding the island of Saipan. This project greatly expanded upon the effort started in 2012. The specific objectives of this project are reviewed in the technical summary section (see indented numbers 1-3). The decision-support framework is the first of its kind developed on the back of an ecological resilience assessment. It was developed through extensive collaboration with local managers in CNMI.

5. ORGANIZATION AND APPROACH

Eleven variables ('resilience indicators') were included in the resilience assessment, based on the site selection framework described in McClanahan et al. (2012). Variables were measured or assessed in the field and via desktop analyses.

Field sampling In the spring of 2012 the research team surveyed 29 forereef sites on Saipan and in the spring 2014 the same team sampled an additional 24 sites in Rota and 25 sites on Tinian and Aguijan at the 30-foot contour. Variables assessed in the field were macroalgae cover, bleaching resistance, coral recruitment, coral diversity, herbivore biomass, coral disease and anthropogenic physical impacts. Resilience indicator variables are in bold and anthropogenic stressors are in bold italics.

- **Macroalgae cover (%)** is the average percent of points classified as fleshy macroalgae (>5 cm in height) on three 50-m point-intercept transects where points were classified each 50 cm.

The coral community was assessed using 12-16 0.25 m^2 quadrats thrown in a stratified random manner ~10 m on left and right sides of the three 50-m transect tapes used to assess macroalgae cover. All stony corals were identified to species and the longest diameter and perpendicular diameter measured. Species were classified from 1-5 from low to high bleaching susceptibility. Rankings were produced using an expert focus group that reviewed the literature, as well as data from the only well documented bleaching event in Saipan (in 2001).

- Corals with a "3" or less were considered resistant and **Bleaching resistance (%)** is the percent of the community made up of resistant species.
- **Coral recruitment (#/m^2)** is the average density of juvenile corals with a geometric mean <5 cm within the assessed quadrats; we assess *new* recruits so exclude massives that commonly have parts of larger colonies that are <5 cm (e.g., *Porites lobata*).
- **Coral diversity** (unitless) is the inverse of Simpson's index of diversity, which is based on the frequency each species was observed and the species richness. The resultant value ranges from 0-1 and assesses the probability two species selected at random from the sampled community will be different, so higher percentages equate to higher diversity.

The fish community was assessed using three 3-minute 5-meter radius stationary point counts (SPCs) performed along each of the 50 m transect lines (9 SPCs total, 3 per line). The SPC counts were performed prior to any other activities to minimize diver influence while rolling out the initial transect lines. All counts were performed by the same diver, creating a high level of consistency between sites and sample years.This provided a precise distance with which to reference SPC boundaries. All herbivorous fish and all other fish larger than 8 cm in body length were identified to species, and their length was estimated to the nearest cm. The weight of each fish in grams was then calculated using the standard equation W = aLb, where W is weight, L is length, and a and b are coefficients specific to each species. The coefficients used were sourced from NOAA's Coral Reef Ecosystem Division. Species were classified as herbivores using IUCN's classification for these species (Green and Bellwood 2009).

- Herbivores were then grouped as browsers, grazers/detritivores, or scrapers/excavators, and the average biomass was calculated in kg/ha for each group. These values were then averaged to produce the final **Herbivore biomass (kg/ha)** value, which equally weights the importance of the major herbivore functional groups.
- Prevalence surveys of **Coral disease** could only be conducted at a third of the survey sites so coral disease is excluded from the resilience analysis. The conducted surveys indicate total coral disease to have an average prevalence ±1 sd of 3.47±2.65%.
- **Anthropogenic physical impacts** (caused by anchoring, fishing equipment, or divers/snorkelers) were not observed and so are also excluded from the resilience analysis.

Desktop Variables assessed using remote sensing and GIS software were temperature variability, land-based sources of pollution and wave exposure and accessibility. For temperature variability, observed sea surface temperature (SST) data for the period 1982-2012 was obtained from NOAA Pathfinder Version 5.2 (4-km resolution, Casey et al. 2010).

- **Temperature variability (unitless)** is the standard deviation of warm season temperatures with warm season defined as the three months that center on the month with the maximum monthly mean temperature for the 1982-2012 period.

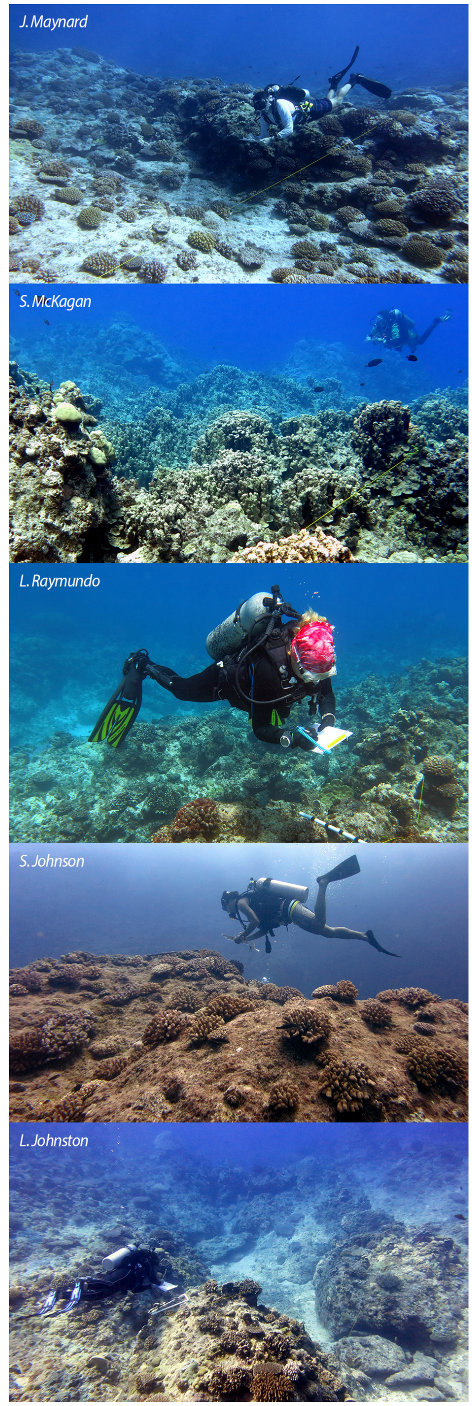


Figure 1. Scientific divers from our project team assessing benthic community cover (Maynard), fish diversity and biomass (McKagan), coral health (Raymundo), and coral diversity and recruitment (Johnson and Johnston).

Land-based sources of pollution and fishing both represent putative localized stressors across Micronesia reef ecosystems (Houk et al. 2012).

The proxy for ***Land-based sources of pollution*** was developed using geographic information system (GIS) layers pertaining to watershed size, topography, land use and human population (land use data from United States Forest Service, http://www.fs.usda.gov/r5). The proxy represented a measure of land-based influence to coastal water quality based upon the coverage of barren land, urbanized areas, and human populations. Digital elevation models (i.e., topographic data) were used to define watershed boundaries and flow patterns for surface discharge, and then each site was attributed to an adjacent watershed. The proxy was calculated by multiplying standardized values for altered land use and human populations (i.e., land use x human population interactions).

A primary driver of fishing pressure in CNMI is access, which is influenced by wave height and distance to boating access. Site-based wave exposures were calculated based upon 10-year wind-speed records, fetch distances to the nearest reef or land feature, and angles of exposure (Quikscat wind datasets from 1999 to 2009; https://winds.jpl.nasa.gov/, wave energy in J/m^3, full description found in Ekebom et al. 2003, Houk et al. 2014).

Wave exposure and accessibility was calculated by multiplying standardized wave energies and distances to the nearest points of fishing access (i.e., wave and distance interactions). Once calculated the scale is reversed for this proxy by subtracting from 1 meaning high values equal high access. The results for Saipan aligned closely with both a managers survey performed for Saipan and perceived access limitations created by trade winds on the windward (east) side of Saipan. The value for this proxy was considered to be '0' for all protected areas.

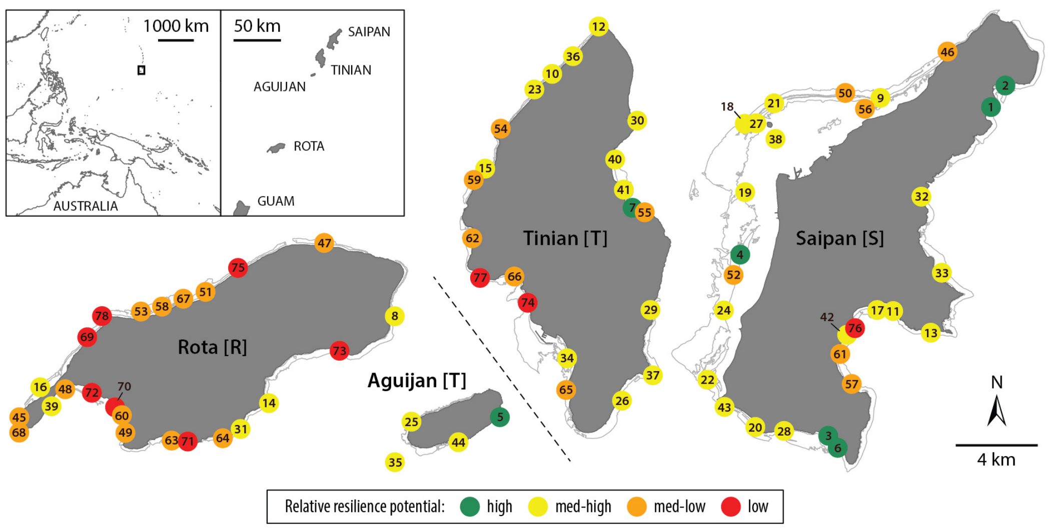
Data analysis The following variables are included in the assessment of resilience potential: macroalgae cover (MA), bleaching resistance (BR), coral recruitment (CR), coral diversity (CD), temperature variability (TV) and herbivore biomass (HB). Both inter-island and intra-island analyses were completed. Values for each variable were first normalized to a uni-directional scale of 0-1 where high scores were always good scores. Sites were then compared both against sites around all of the surveyed islands and only to sites from the same island to create inter and intra-island scores, respectively. The normalized scores were then scaled based on differences in the perceived importance of each variable to resistance and recovery (from Table 2 in McClanahan et al. 2012). In the McClanahan et al. (2012) study, bleaching resistance had a perceived importance score of 15.57, which is 36% greater than the lowest perceived importance score for our variables of 11.43 for coral recruitment. Therefore, scaling multipliers used in our study were as follows: MA – 1, BR – 1.36, CR – 1, CD – 1.08, TV – 1.22, HB – 1.02. The scaled scores were then averaged and normalized again by dividing by the maximum value, which resulted in resilience potential scores ranging from 0-1, with all scores expressed as a percentage of the site with the greatest score.

Relative classifications for resilience scores were as follows: high (>avg+1sd), med-high (<avg+1sd and >avg), med-low (<avg and >avg-1sd), low (<avg-1sd). These classes were used to colour grade resilience potential and the distribution of data for all assessed variables as follows: high – green, yellow – med-high, orange – med-low, red – low.

The resilience scores, resilience indicator variables and proxies for anthropogenic stress were all used to identify sites that warrant management attention based on 9 criteria, the first 2 of which were above average values for land-based sources of pollution or wave exposure and accessibility. The remaining 7 management criteria are named and derived as follows: (L) **L**and-based sources of pollution – above average resilience potential and land-based sources of pollution, (H) **H**erbivore ecology – below average herbivore biomass and above average fishing access, (W) **W**ave exposure and accessibility – above average resilience potential and wave exposure and accessibility, (P) **P**lace-based management – high or low resilience potential and are currently outside established no-take MPAs, (B) **B**leaching vulnerable - low bleaching resistance and low herbivore biomass, (C) **C**oral translocation/reef restoration – above average resilience potential and low coral diversity or coral cover, (T) **T**ourism potential – above average coral diversity and above average fish species richness and biomass and above average wave exposure and accessibility. A map of locations that meet each of these criteria was produced.

6. PROJECT RESULTS

The average final score for resilience potential for the inter-island analysis is 0.81 ($\pm$0.06), meaning values $\leq$0.75 are considered low and values $\geq$0.87 considered high. There were 7 sites with high relative resilience potential and 10 with low (37 med-high and 24 med-low, Figure 2).



1 (1) [S] - Nanasu Reef
2 (2) [S] - Bird Island
3 (4) [S] - Obyan Beach
4 (3) [S] - Lighthouse Reef
5 (4) [T] - East Aguigan Falls
6 (5) [S] - Boy Scout
7 (1) [T] - Unai Masilok
8 (3) [R] - As Dudo_MMT
9 (7) [S] - Pau Pau
10 (6) [T] - Unai Babui_MMT
11 (6) [S] - Laolao Bay East
12 (10) [T] - Tahgong Point
13 (8) [S] - Forbidden Island
14 (1) [R] - Haina Point
15 (3) [T] - Lamanibot
16 (2) [R] - West Harbor_MMT
17 (10) [S] - Laolao Bay Mids
18 (11) [S] - Lanyas
19 (9) [S] - Peysonnelia Reef
20 (14) [S] - Coral Ocean Point
21 (12) [S] - Elbow Reef
22 (13) [S] - Point Break Reef
23 (5) [T] - Unai Chulu
24 (15) [S] - MMT - Outside Grand Hotel
25 (12) [T] - Aguigan Island_MMT
26 (8) [T] - Suicide Cliff
27 (16) [S] - MMT - Managaha MPA
28 (18) [S] - Ladder Beach
29 (9) [T] - Barangka
30 (2) [T] - Asiga Point
31 (4) [R] - Agatasi
32 (17) [S] - Old Man By the Sea
33 (19) [S] - Tank Beach
34 (16) [T] - Dynasty_MMT
35 (13) [T] - Naftan Rock
36 (17) [T] - Unai Lamlam
37 (11) [T] - Puntan Kastiyu
38 (20) [S] - MMT - Managaha Patch Reef
39 (7) [R] - East Wedding Cake
40 (14) [T] - Unai Asiga
41 (7) [T] - Long Beach_MMT
42 (22) [S] - North Dakota
43 (21) [S] - Agingan Point
44 (18) [T] - Happy Days
45 (5) [R] - Senhanom Wall
46 (24) [S] - Wing Beach
47 (9) [R] - Mochong
48 (12) [R] - Sasanhaya_MMT
49 (6) [R] - Coral Gardens_MMT
50 (23) [S] - Achu Dangkulu
51 (10) [R] - Coconut Village
52 (25) [S] - Oleai Rocks
53 (8) [R] - Sunset Villa_MMT
54 (19) [T] - Puntan Lamanibot Sanhilo
55 (15) [T] - Masilok Beach Wall
56 (28) [S] - Achugao
57 (26) [S] - South Laolao
58 (16) [R] - Iota Salvage_MMT
59 (22) [T] - Puntan Lamanibot Sampapa
60 (15) [R] - Honey Gardens
61 (27) [S] - South Dakota
62 (21) [T] - Atgidon
63 (14) [R] - Okgok_MMT
64 (11) [R] - Malilok Point
65 (20) [T] - South Point_MMT
66 (23) [T] - Barcinas Bay_MMT
67 (13) [R] - Teteto
68 (17) [R] - Harnom Point
69 (18) [R] - Cave Museum_MMT
70 (20) [R] - Takta Sagua
71 (19) [R] - Talakhaya_MMT
72 (22) [R] - Joanne's Reef
73 (21) [R] - South I Chenchon Park
74 (24) [T] - Leprosarium
75 (23) [R] - Rota Resort_MMT
76 (29) [S] - Tuturam
77 (25) [T] - Puntan Diapblo
78 (24) [R] - Sailigai Point

Figure. 2. Inter-island relative resilience potential of the 78 forereef survey sites in the Commonwealth of the Northern Marianas Islands (CNMI). Resilience rankings are from highest to lowest resilience score; the average score for the 6 resilience indicators after normalizing and scaling scores among islands (see Table S2a, b). Intra-island rankings are shown in brackets next to the inter-island ranking (site number) shown here (see also Figure 2). Sites with '_MMT' in the name refer to sites surveyed by the marine monitoring team of the Bureau of Coastal and Environmental Quality in CNMI.

The highest-scoring site, Nanasu Reef, is on the exposed side of Saipan (see 1 in Figure 2) and has high or med-high scores for four of six variables (has low bleaching resistance and temperature variability).

The lowest scoring site was Sailigai Point on the northern leeward side of Rota; the score of 0.62 means the lowest score for relative resilience potential is 38% lower than the highest resilience score. Sailigai Point has low or med-low scores for all variables except temperature variability. Five of the 7 high resilience sites are near Saipan and two are reef sites of Tinian. Seven of the 10 lowest-scoring sites are reef sites of Rota. In Rota, 5 of the 18 surveyed sites are med-high; the rest are med-low or low. In contrast, 16 of 25 surveyed sites of Tinian/Aguijan are med-high or high and 21 of 29 sites of Saipan are med-high or high (Figure 2).

The average final score for relative resilience potential for the intra-island analysis is ~0.85 for all three islands, with variance measured by standard deviation greater for sites of Rota (0.10) than for Tinian/Auijan (0.8) or Saipan (0.05). The distribution of sites among the relative classes resulted in ≥2 low and high resilience sites at each island with higher proportions of relatively high and low resilience sites at Rota due to the greater variation in the resilience scores there. The general pattern is that the sites with high intra-island resilience potential are on the exposed sides of the islands and thus least accessible to humans, which applies to 7 of the 9 total high resilience sites (Figure 3). Six of the 9 total low resilience sites are within 10 km of human communities. All established marine protected areas, Bird Island and Mañagaha at Saipan [2, 27, Figure 2] and Sasanhaya and Coral Gardens at Rota [48, 49, Figure 2], are med-high or high resilience sites.

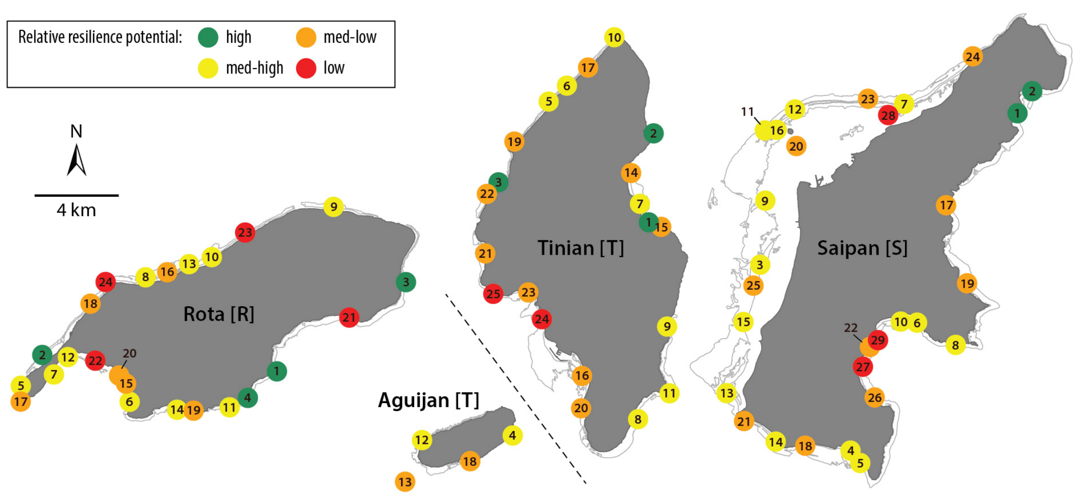


Figure 3. Intra-island relative resilience potential of the 78 forereef survey sites in the Mariana Islands. Resilience rankings are from highest to lowest resilience score; the average score for the 6 resilience indicators after normalizing and scaling scores within islands (Tinian and Aguijan are grouped). Relative classifications for resilience scores and site names are per Figure 1.

7. ANALYSIS AND FINDINGS

The criteria we set to identify sites that warrant management attention (see end of Section 5) represent an innovative approach to ensuring the results of ecological resilience assessments can inform management actions. These represent the major findings of our research, as this is what our local manager partners in CNMI can use to both target actions and develop education and outreach materials for engagement with community members and stakeholders.

Nine approaches in total were used to identify sites that warrant management attention, all of which were derived from the inter-island analysis results (see Figure 2). The first two are sites with either above average values for land-based sources of pollution or wave exposure and accessibility. Sites with above average values for land-based sources of pollution are generally in close proximity to human communities where the percent of the watersheds made up by urban and cleared areas is greatest (see 19, 38, 76 for Saipan and 66, 74 for Tinian/Aguijan, Figure 2). Sites with above average values for wave exposure and accessibility (meaning high access) are all on the leeward sides of Saipan and Tinian/Aguijan. Results from the 7 other criteria set for identifying sites warranting management attention are all summarized in Figure 4.

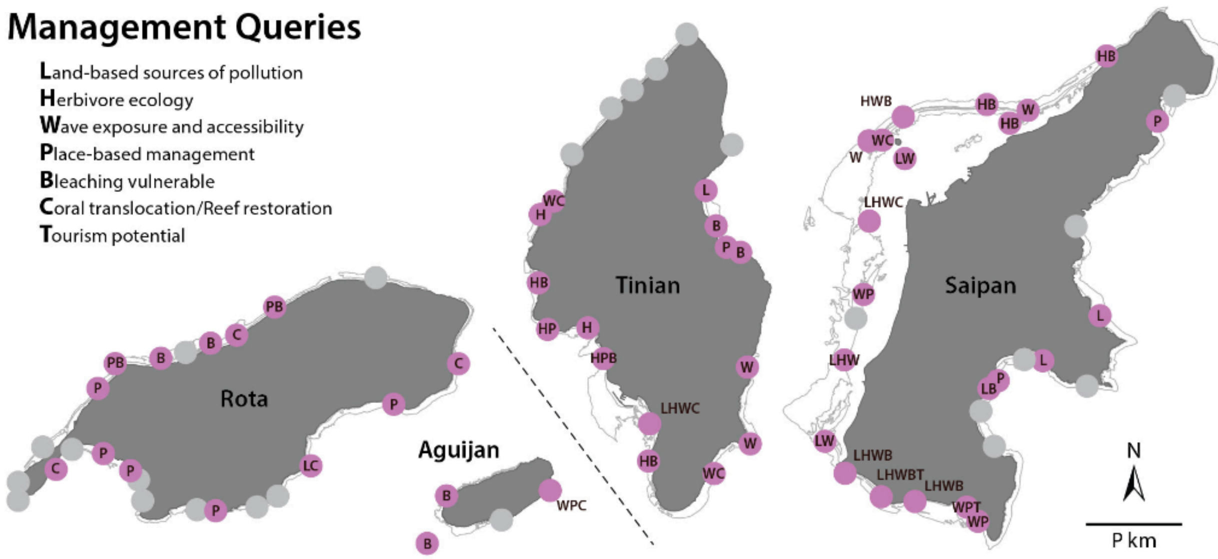


Figure 4. Results of 7 custom criteria set to identify sites that warrant management attention from the inter-island analysis. Bold first letters are used in the map to denote sites that meet the criteria for the query; sites with multiple letters meet multiple criteria. See end of Organization and Approach section for the methods for each query.

Sites meeting the **L**and-based sources of pollution query are (n=13) at all islands and on both the leeward and windward sides of the islands (see letter codes/locations meeting the queries in Figure 4). **H**erbivore ecology sites (n=16) are on the leeward sides of Saipan and Tinian/Aguijan. **W**ave exposure and accessibility sites (n=20) are all on the leeward side of Saipan and southern end and leeward side of Tinian/Aguijan. **P**lace-based management targets are at each of the islands; these mostly refer to high resilience potential sites at Saipan and Tinian/Aguijan and low resilience sites at Rota. **B**leaching vulnerable sites (n=20) are in northern and southern Saipan, on the leeward and windward sides of Tinian, include 3 of 4 surveyed sites at Aguijan, and are in northwestern Rota. There are only 10 sites that meet the query for **C**oral translocation/reef restoration and there are $\geq$2 at each island including sites within the Saipan lagoon, in northern and southern Tinian and on all sides of Rota. The very best targets for coral translocation/reef restoration may be As Dudo_MMT and East Wedding Cake of Rota (8, 39 on Figure 1). These are med-high resilience sites (Figure 1) that meet this criteria but also have below average scores for both land-based sources of pollution and wave exposure and accessiblity meaning transplanted corals may have greater survivorship here. There are only two sites that meet all of the criteria **T**ourism potential and both are in south Saipan (Lighthouse Reef and Coral Ocean

Point, 3, 20 in Figure 1). There are a total of 23 sites that do not meet any of the 7 custom criteria. Importantly, there could be other reasons than those set here that many or all of those sites may warrant management attention. Our manager partners are identifying appropriate actions to reduce stress and support resilience at the identified sites and will consider the results presented above and in Figure 4 during planning exercises in this and the coming years.

8. CONCLUSIONS AND RECOMMENDATIONS

There are two broad results that summarize the content presented within sections 6 and 7. (1) Resilience is highly spatially variable within and among islands. There is a normal distribution among sites for the inter- and intra-island analyses with ~75% of sites having scores within 1 standard deviation of the average and ~25% of sites being outside the normal range and having high or low relative resilience potential. (3) The ecological resilience assessments results can inform a large range of types of decisions when queries are set that combine resilience assessment results and proxies of anthropogenic stress.

We did not encounter any problems during the project. All project tasks set by our team were completed. If we or others undertake a similar project again, we would use many of our methods again though this science is rapidly advancing so future projects would adapt rather than exactly replicate what is described here. The most important and logical next steps involve overlaying our resilience assessment results with the results of statistical or dynamical downscaling of climate model projections of climate change impacts such as coral bleaching. This will be possible under a new PICSC grant to these co-PIs and will result in our identifying two types of priority conservation sites based on climate vulnerability: 1) sites with high resilience potential that are also temporary refugia from the increased sea temperatures that cause coral bleaching (low vulnerability sites), and 2) sites with low resilience potential projected to experience annual bleaching conditions earliest (high vulnerability sites). Low vulnerability sites may have the greatest chance of persisting in an era of increasing disturbance frequencies under climate change and could be targets for long-term strategic actions to reduce anthropogenic stress. Actions to reduce anthropogenic stress may be most urgent at high vulnerability sites and these may be locations that managers need to consider preparing for reef restoration. The results of our future analyses and the reporting of those results such that managers can take action will involve extensive community and stakeholder engagement during 2015 and 2016.

9. MANAGEMENT APPLICATIONS AND PRODUCTS

Our local manager partners are Steven McKagan, NOAA Fisheries liaison for the CNMI, Dr. Lyza Johnston, the lead scientist for the Bureau of Environmental and Coastal Quality's (BECQ) Marine Monitoring Team (MMT), and Steven Johnson, a research scientist with BECQ and MMT. Our decision analysis methods and support tool are reviewed within the Analysis and Findings section. Our fieldwork has doubled the number of reef locations in CNMI for which baseline survey information is available, which will be foundational for new management plans. The results of our research will be used to: 1) aid all local agencies in meeting regulations associated with the presence of ESA-listed 'Threatened' coral species (we observed the Threatened coral *Acropora globiceps* at 25 locations in CNMI); 2) inform site selection and project success for compensatory mitigation requirements in the region; 3) ensure that resilience to climate change is a factor when considering targets for place-based management (see **P** in Figure 4); 4) inform several education and outreach programs; 5) target surveys of bleaching impacts during anomalously warm summers, and 6) aid managers all over the world in undertaking similar projects whereby ecological resilience assessments are used to develop spatial decision-support frameworks. Our local manager partners state that our study findings will be used for years to come to inform the implementation of management actions and for management planning purposes.

10. OUTREACH

Our team is currently in the final stages of preparing a manuscript for submission to a leading scientific journal. We expect our open access peer-reviewed article to be available by July of 2015. Our methods and project results were discussed at a resilience-based management workshop chaired by the project co-PI in Hawaii in November of 2014. Managers and applied scientists working across the Pacific Islands attended the workshop. The project results will also be shared publicly via a recorded webinar hosted by the PICSC and planned for mid-April, 2015. Our local manager partners have shared the project results at many meetings of local management agencies in Saipan. The results have also been discussed at meetings with the Department of Defense in Hawaii (presentation led by S. McKagan of NOAA Fisheries). The project co-PI updated all of the ecological resilience assessment webpages and manager guidance within The Nature Conservancy's Reef Resilience Toolkit (www.reefresilience.org), which will help others to apply and adapt our methods. Project results will also be shared at the 2016 International Coral Reef Symposium in Hawaii.

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